APD Noise on the Far Detector

R.J. Tesarek

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The Problem

What we've seen

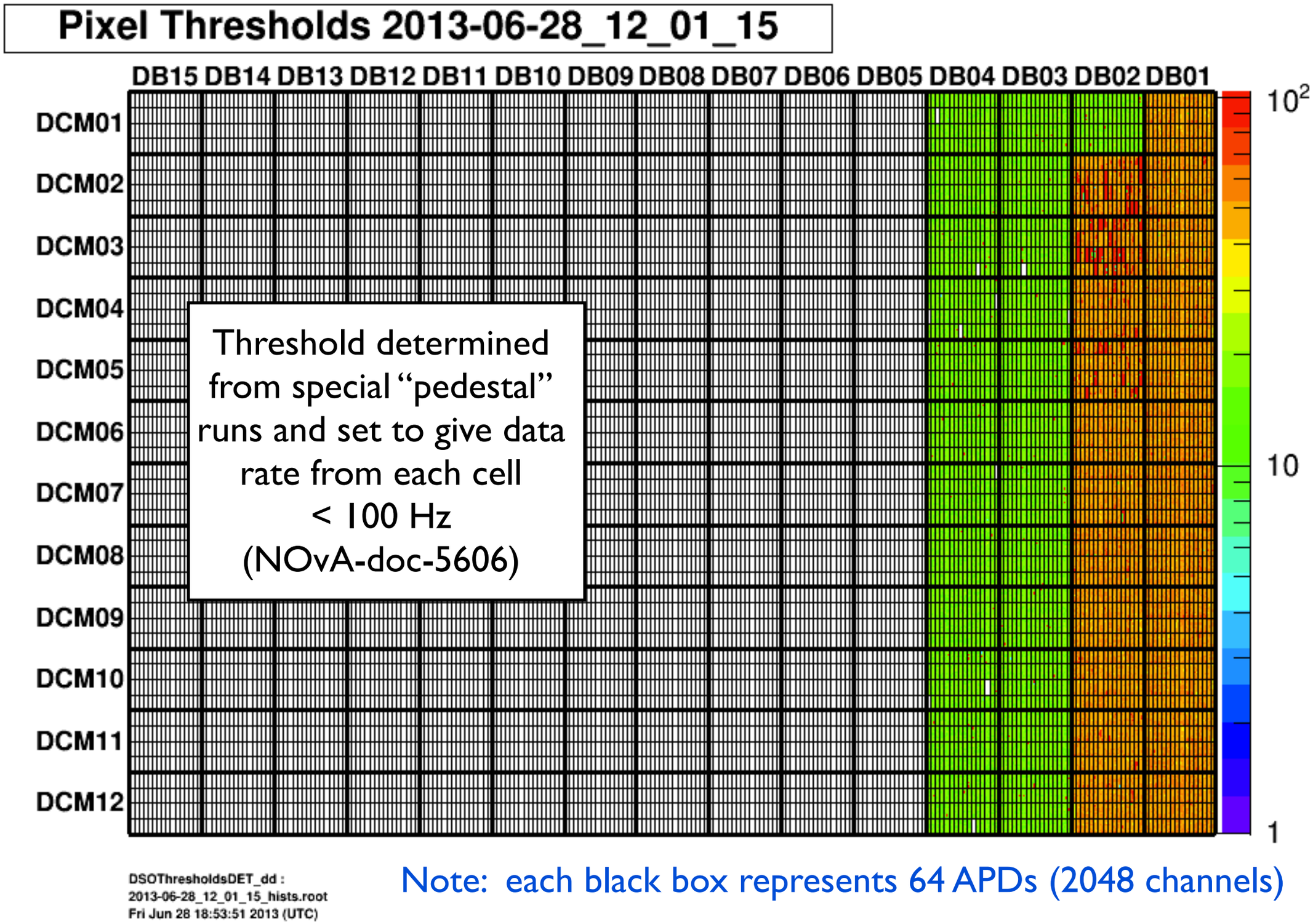
- ~1 di-block (768) APDs installed before 5/20 have initial and continued performance good
- ~1 di-block (768) APDs installed after 5/20 following same installation and checkout procedures show:
  - ➡Pass QA tests prior to installation
  - ➡Higher hit rates (noise) at the nominal bias voltage
  - ➡Higher readout threshold
  - ➡Larger and increasing data rates
- "Training" APDs with high hit rates appears to help (not understood)
- APD "training":
  1. Start with lower bias voltage (300V)
  2. Hold until data rates stabilize
  3. Raise bias voltage 25V and repeat 2. above until nominal bias voltage achieved

➡We do not understand the need for training some of the APDs, what changed to cause this or the long term effects

Nominal APD Conditions:

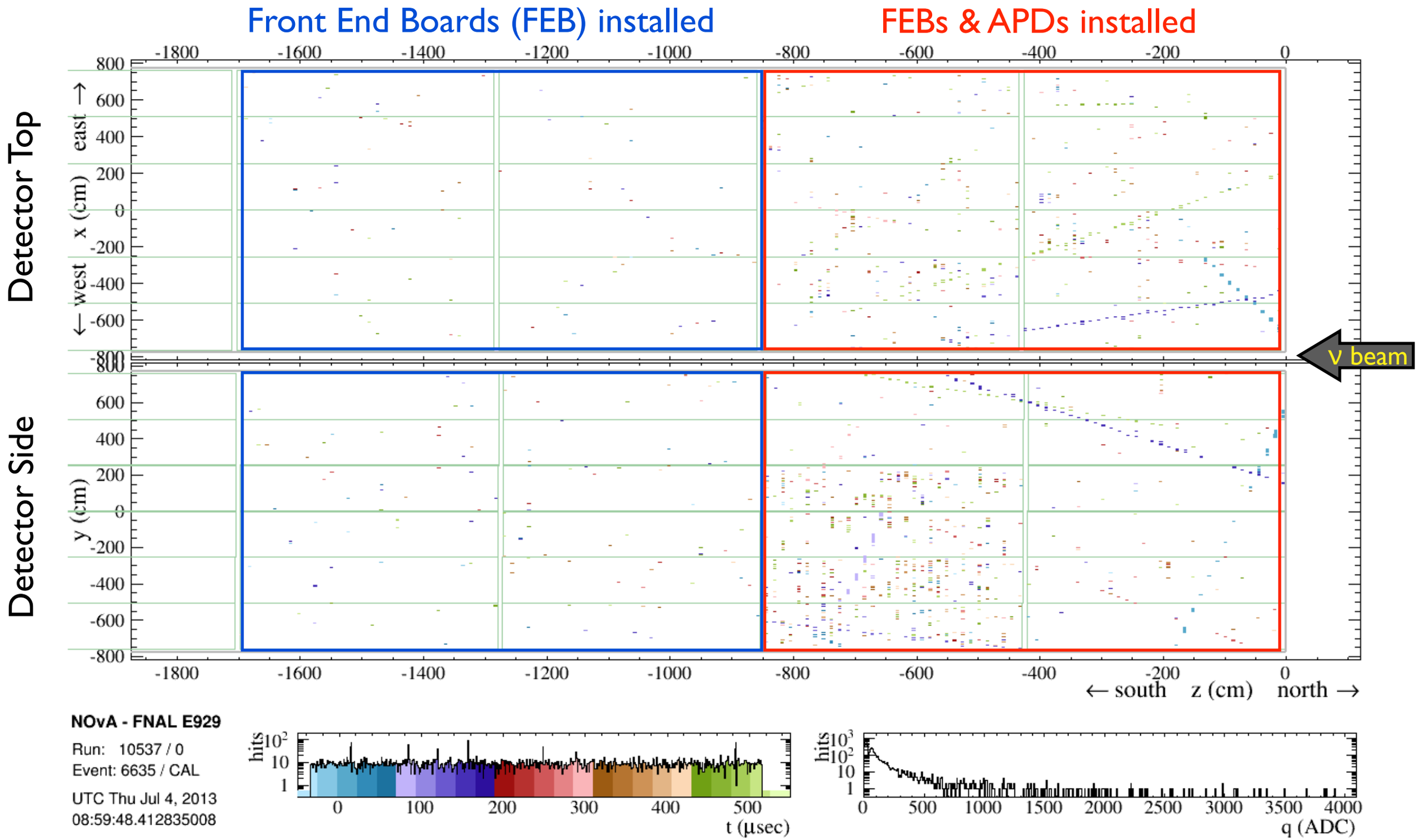
- Water cooled (T ~60F)
- Supply voltage 425V regulated down to 350V (APD bias voltage)
- Dew point in dry gas branches < -30C
- Readout thresholds 50-60 ADC counts
- Parylene coating thickness 0.0004" - 0.0006"

Pixel Readout Thresholds



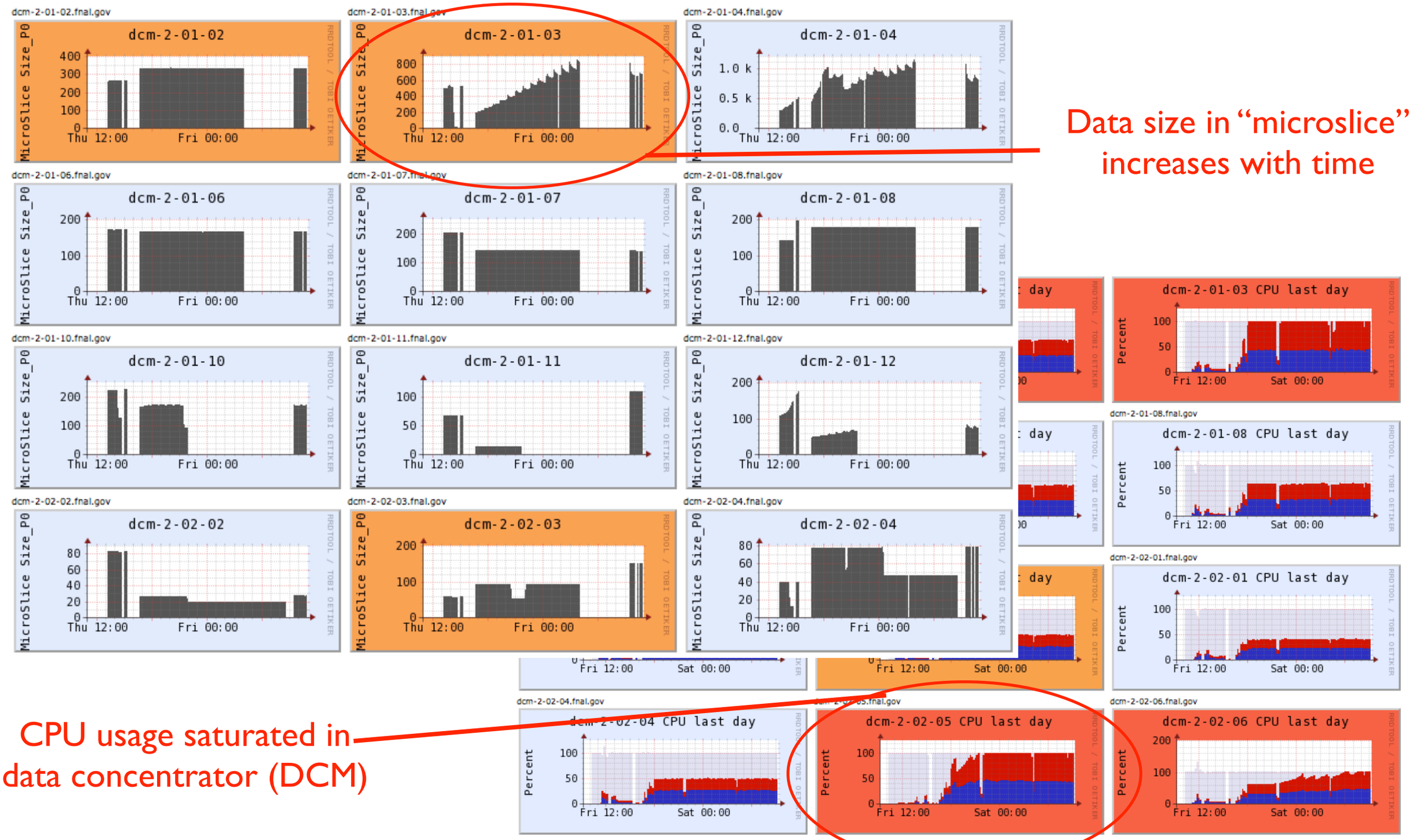
Note: each black box represents 64 APDs (2048 channels)

Noise Example



Note: Each green box above represents 64 APDs installed (2048 detector channels)

Increasing Data Size CPU Saturation



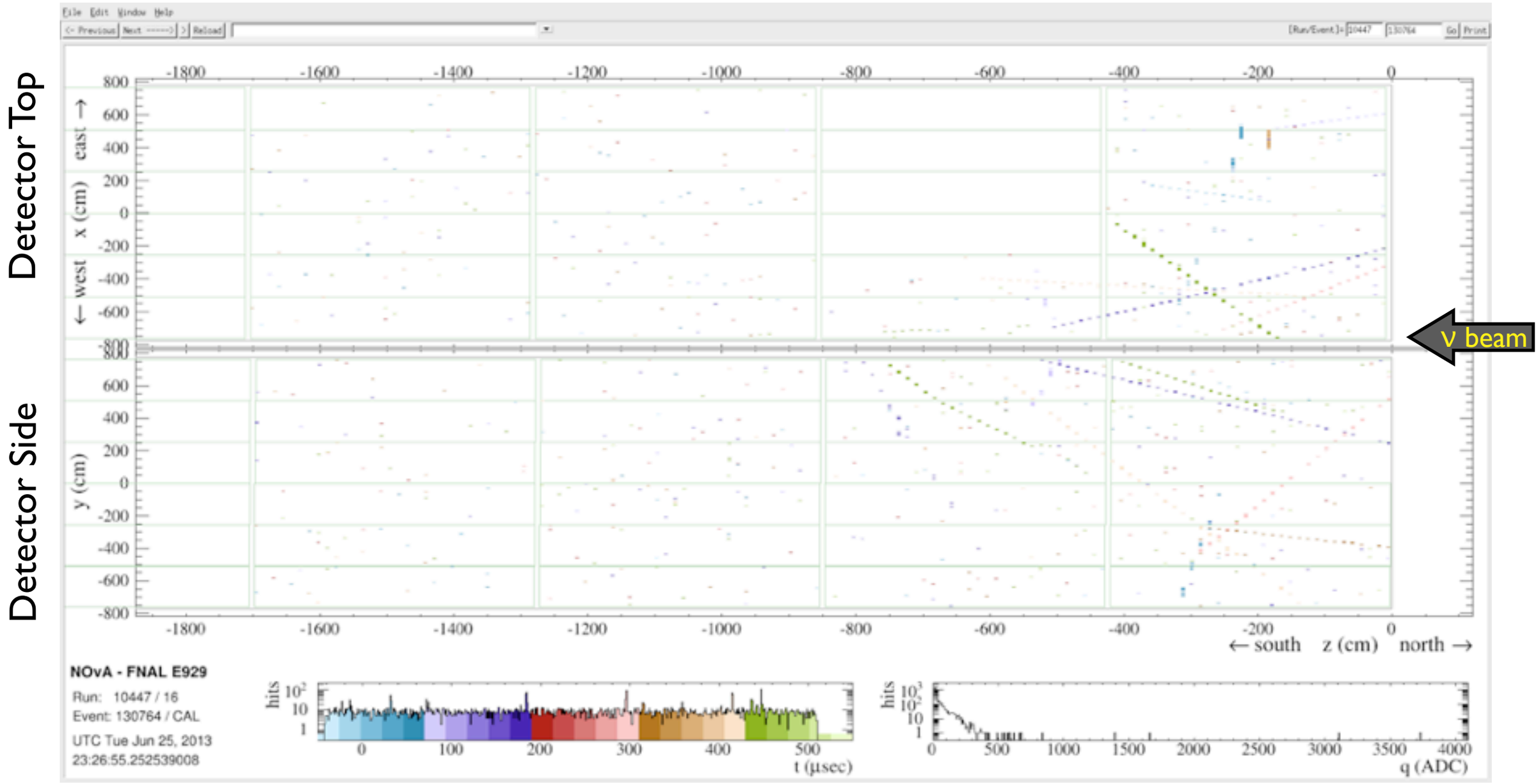
Data size in "microslice" increases with time

CPU usage saturated in data concentrator (DCM)

Evidence that training works

FEBs installed

FEBs & APDs installed



What We Know So Far

Held meeting on 6/11 to discuss strategy/avenues to explore to understand the issue (experts only)

Additional meeting held 7/10 including experts spokespersons, PPD, directorate

What we've learned, improved/ruled out

- Installation at Ash River "unchanged". Handling/testing procedures tightened.
- No position or installer dependence
- Noise not from FEBs (see slide 4)
- Mechanical tolerances unlikely (QA at Ash River/ observations of removed devices)
- Reduced susceptibility of QA equipment to humidity at Ash River
- Short term tests at CalTech/Ash River do not show problems (tests last minutes)
- Noise shows up only after biased for some time (hrs)

Test Parts from Ash River

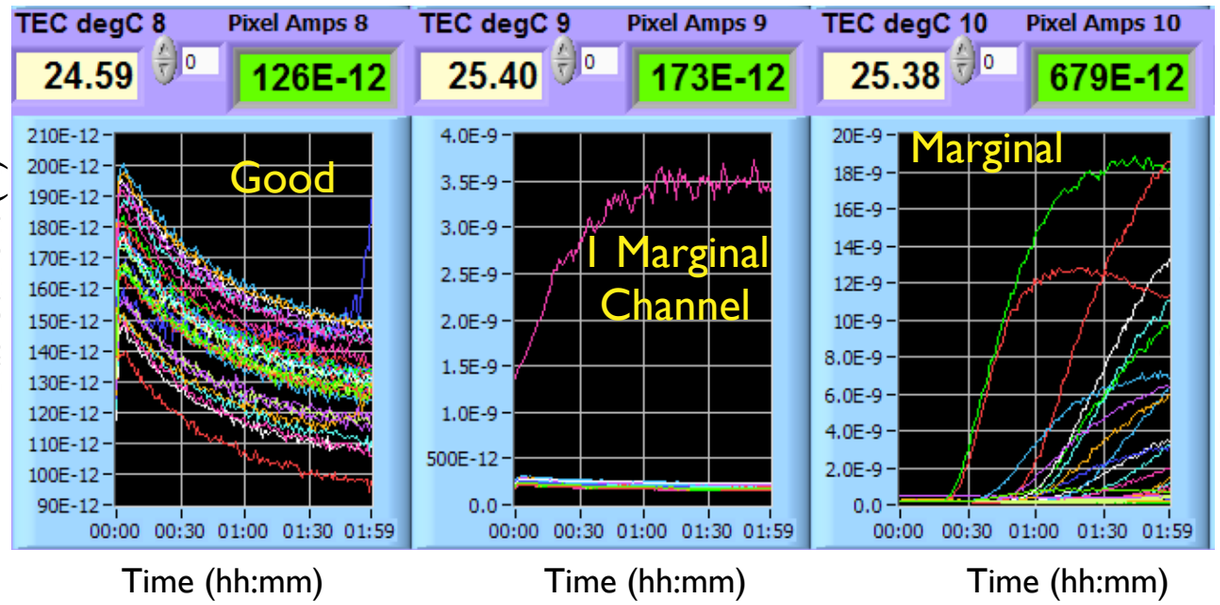
- Failed QA (heat sink seal, bad hoses)
- Noisiest parts removed from far detector

APD Tests at CalTech

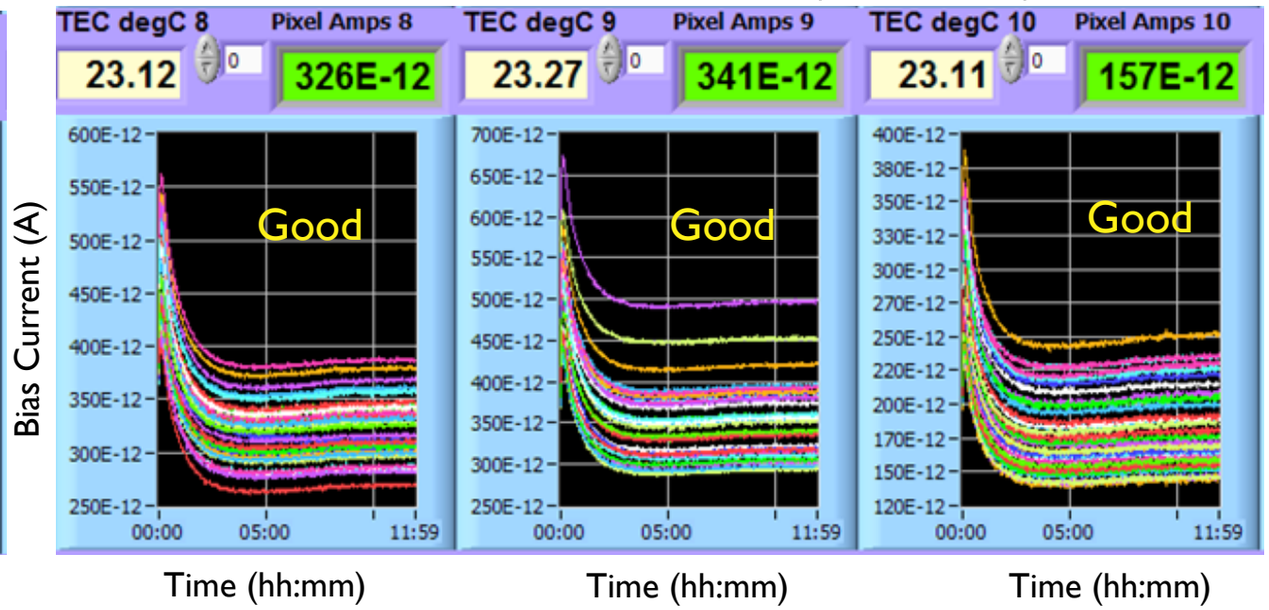
Monitor bias current for longer periods than typical QA tests.

NOTE: Vertical scale changes from plot to plot

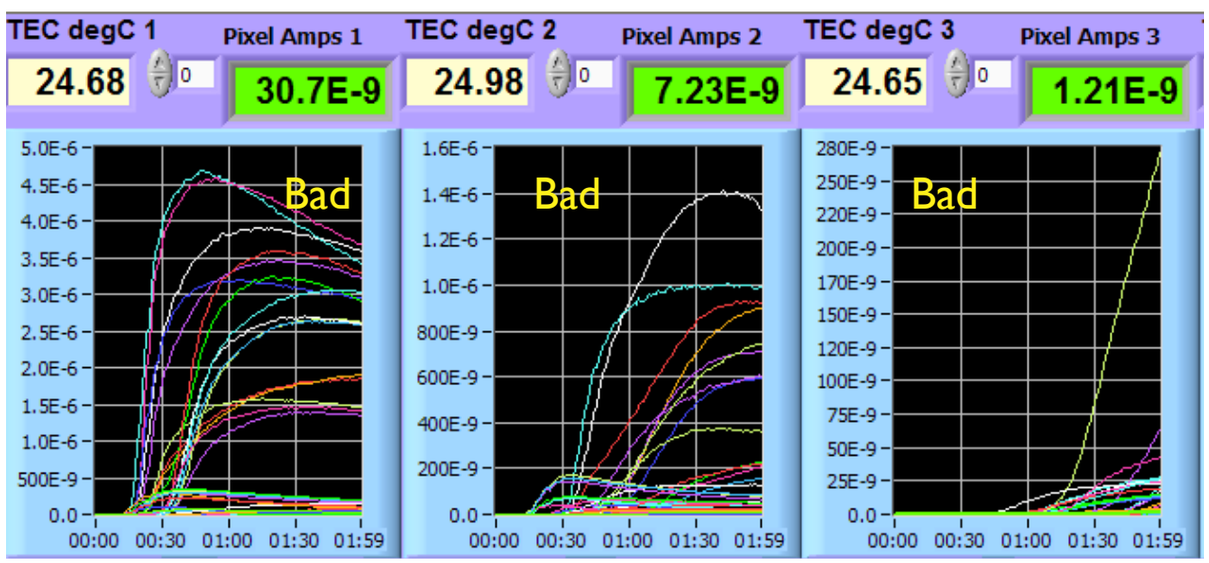
Random APDs from Ash River (2 hr test)



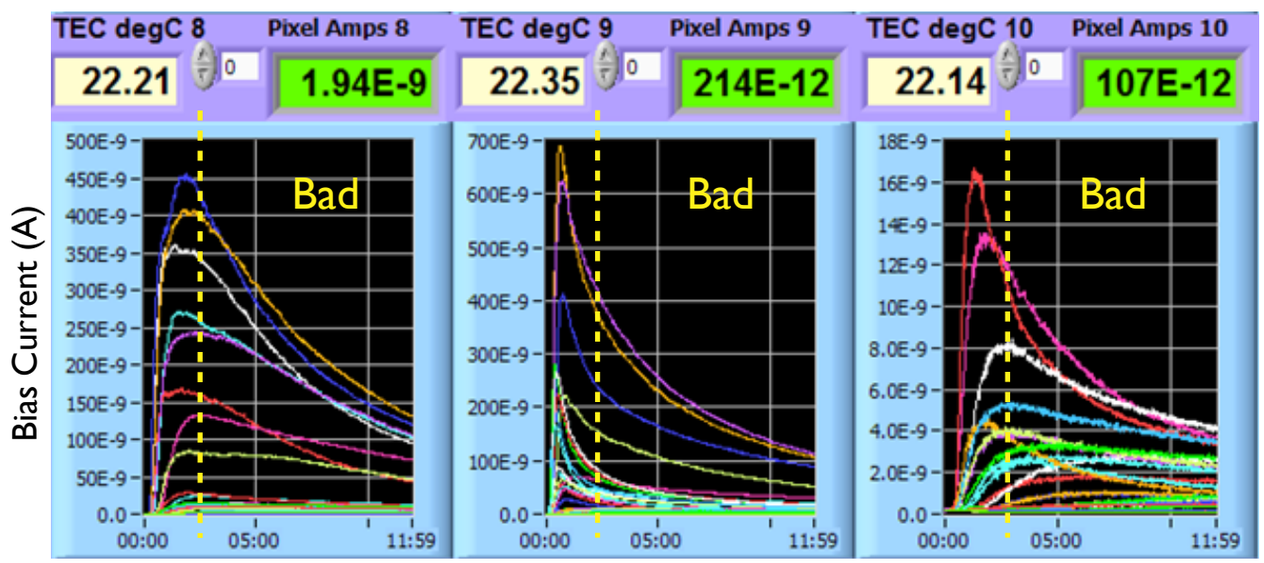
Uncoated Hamamatsu APDs (12 hr test)



Noisy APDs removed from detector (2 hr test)



Batch 10 Parylene Coated Parts (12 hr test)



Conclusions to Date

Qualitatively reproduce the observations on the far detector:

- Short term (QA) tests show no problem
- Problem manifests after some time
- Time on bias voltage decreases current (training)

Additional observations:

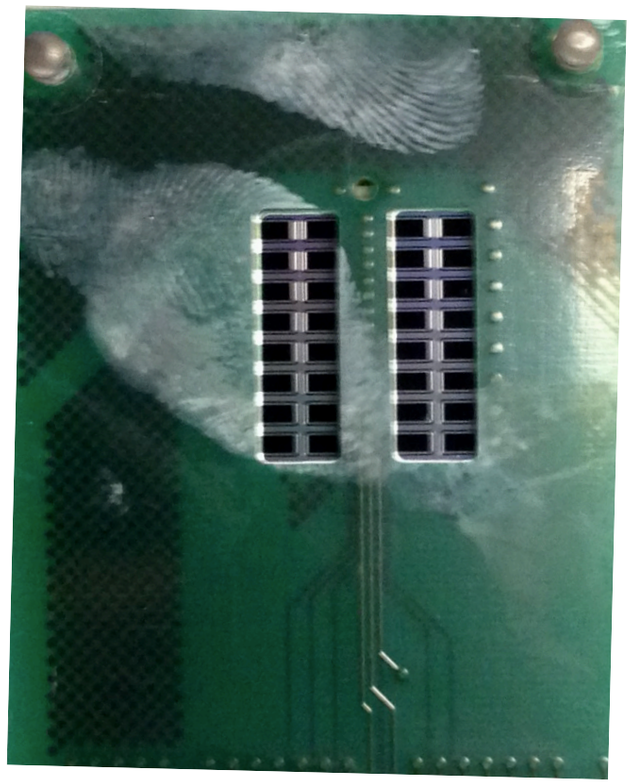
- Recently coated (batch 10) show similar problem features to that seen in noisy APDs from the detector
- APDs sitting on shelf at Advanced Coatings behave as new APDs from Hamamatsu
- APDs baked by Advanced Coatings behave as new APDs from Hamamatsu
- Evidence that power cycling a trained APD does not return that APD to a noisy state

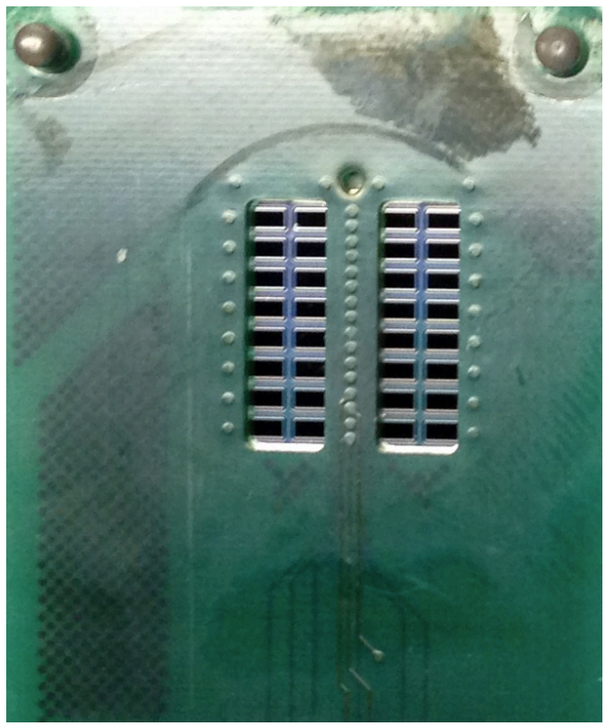
Plans

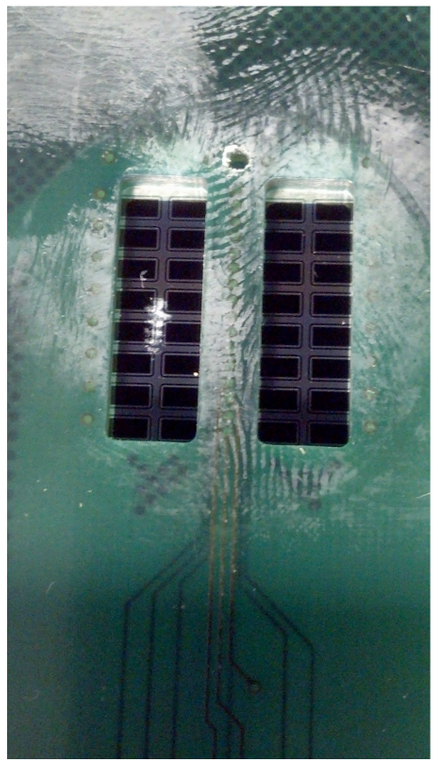
- Additional bench tests at CalTech
- Develop sharper tools to measure pixel rates (Indiana, Minnesota)
- Add P.Rubinov, A.Rhonzhin, (FNAL/PPD) to help perform tests at FNAL
- Install parts on near detector test stand to understand performance of cold APDs
- Work with coater to better understand processing
- B.Flaugher, P.Rubinov, TJ.Sarlina to visit CalTech/Advanced coatings to review APD processing
- Operate APDs with nominal gain (100) and cold (-15C) and monitor performance

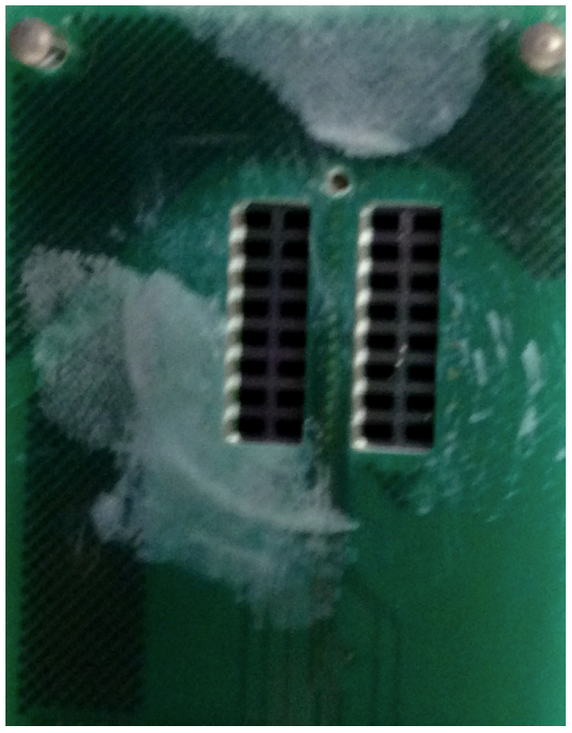
Back Up Slides

Fingerprints Observed at A.R.







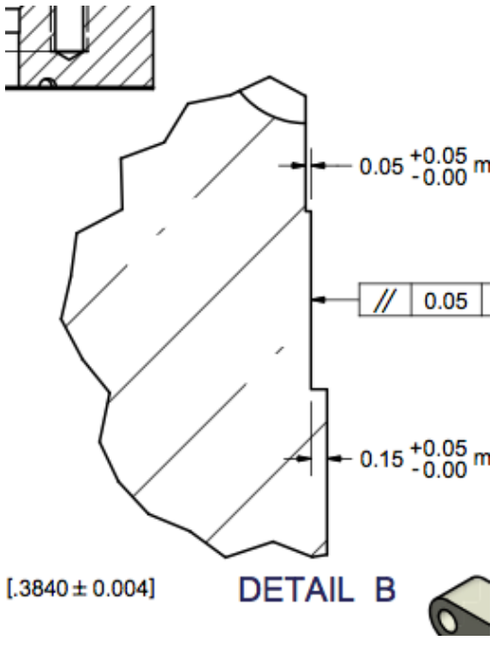


Gloves required for all APD handling at CalTech/Ash River

APD Mechanical Tolerances

Note: ~4% of the optical connectors are measured at Ash River. All are within tolerance (data in NOvA-doc-7469)

APD Back-off from Optical Bosses



-Carrier Board thickness: 0.0622” +/- 0.0021”
(NOVA-DOC-6412, NDOS)
-Parylene Coating: 0.00045” +/- 0.00007”
(Email from Leon)
-Glue: 0.0032” +/- 0.0024”
(NOVA-DOC-6412, NDOS)
-Built-in “Shim”: 0.0059” +/- 0.00197”/0”
(NOVA-DOC-6346)
-PCB back to APD (Gold Bump): ~0.00335” +/- ??(0.00004)
(NOVA-DOC-6474)

Optical boss to coating surface (OBCS) = Shim + Bump – Glue – 2*coating
(Note: The glue shouldn’t add to the calculation if contained to glue channel)
OBCS Value with no glue: 0.00825” +/- 0.002”/0.0002”
OBCS Value with glue: 0.0052” +/- 0.003”/0.0024”

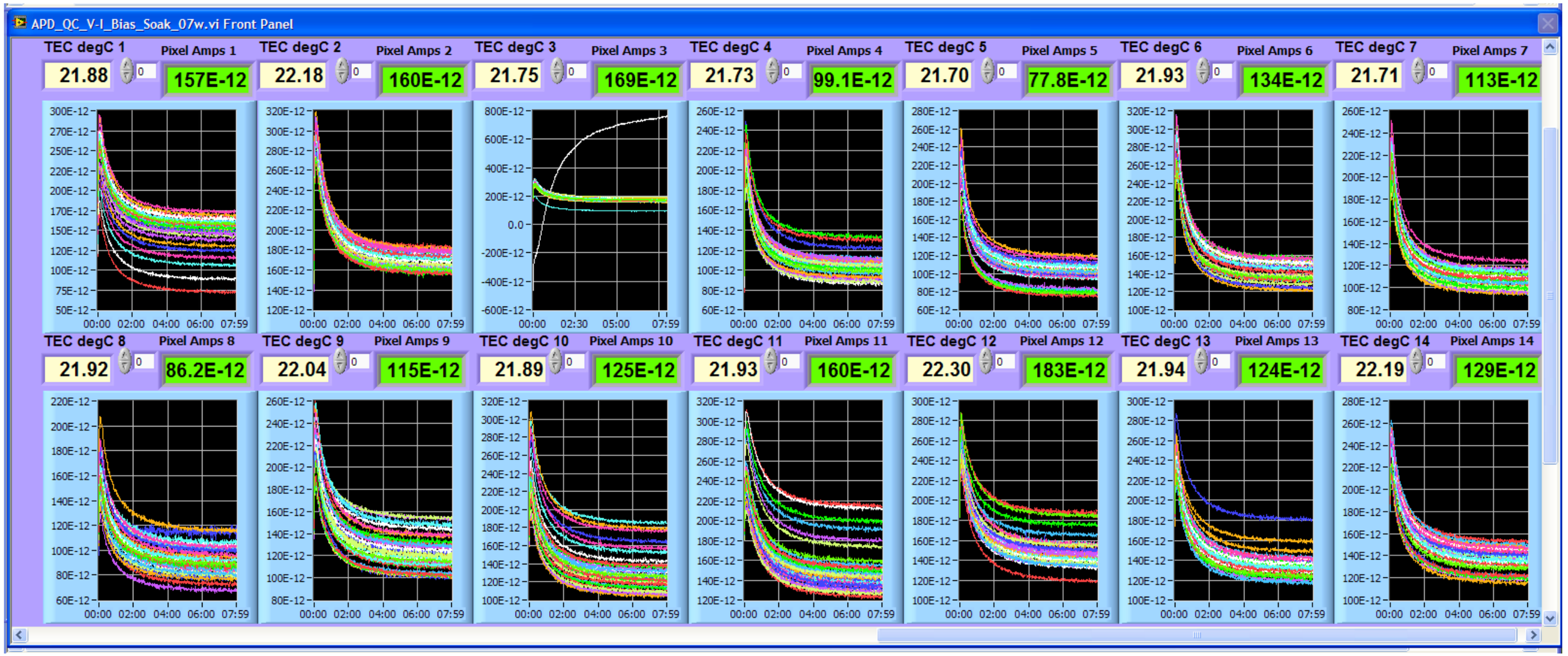
Conclusion: If the parts are in spec, mechanical interference is highly unlikely.
(Do we have recent measurements of the part dimensions?)

Uncoated Parts from Coater

Sample of 1st 14 look perfect in 8 hr test

Instrumentation problem in 3rd plot top row

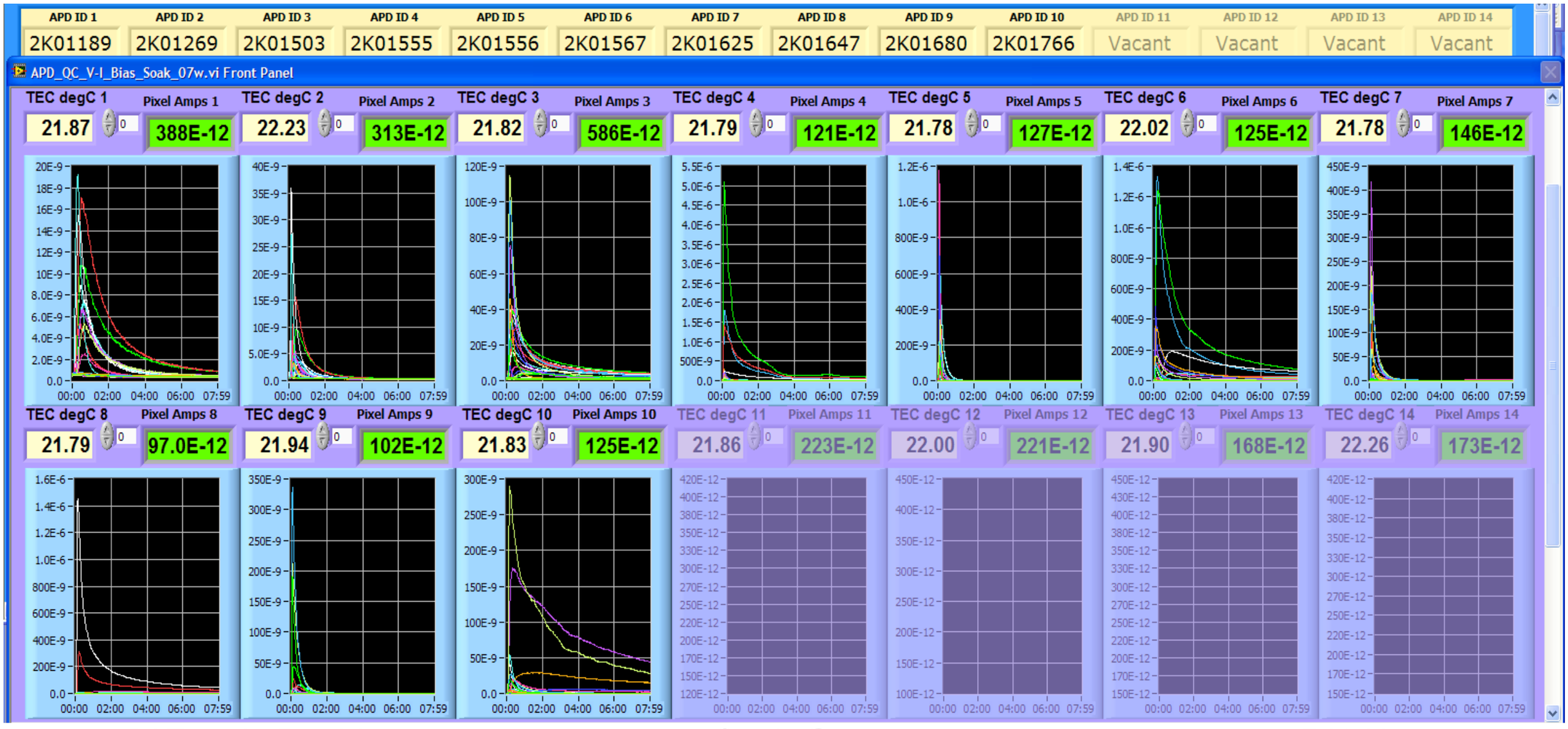
Performance similar to Hamamatsu uncoated parts



Uncoated Parts from Early Coating Batches

All show high early currents that decay away

Several > 1uA, several >100nA

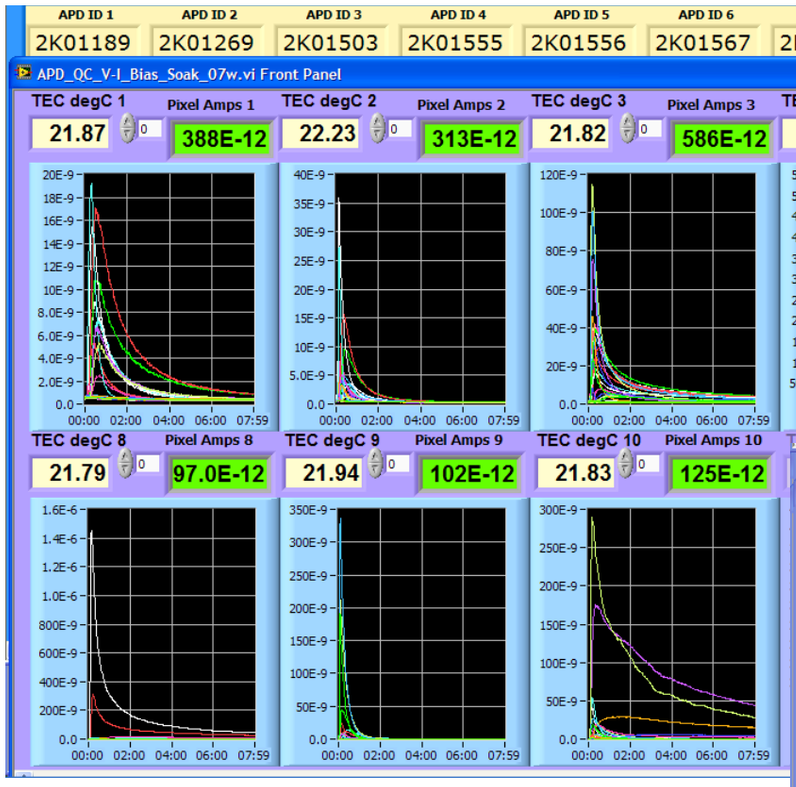


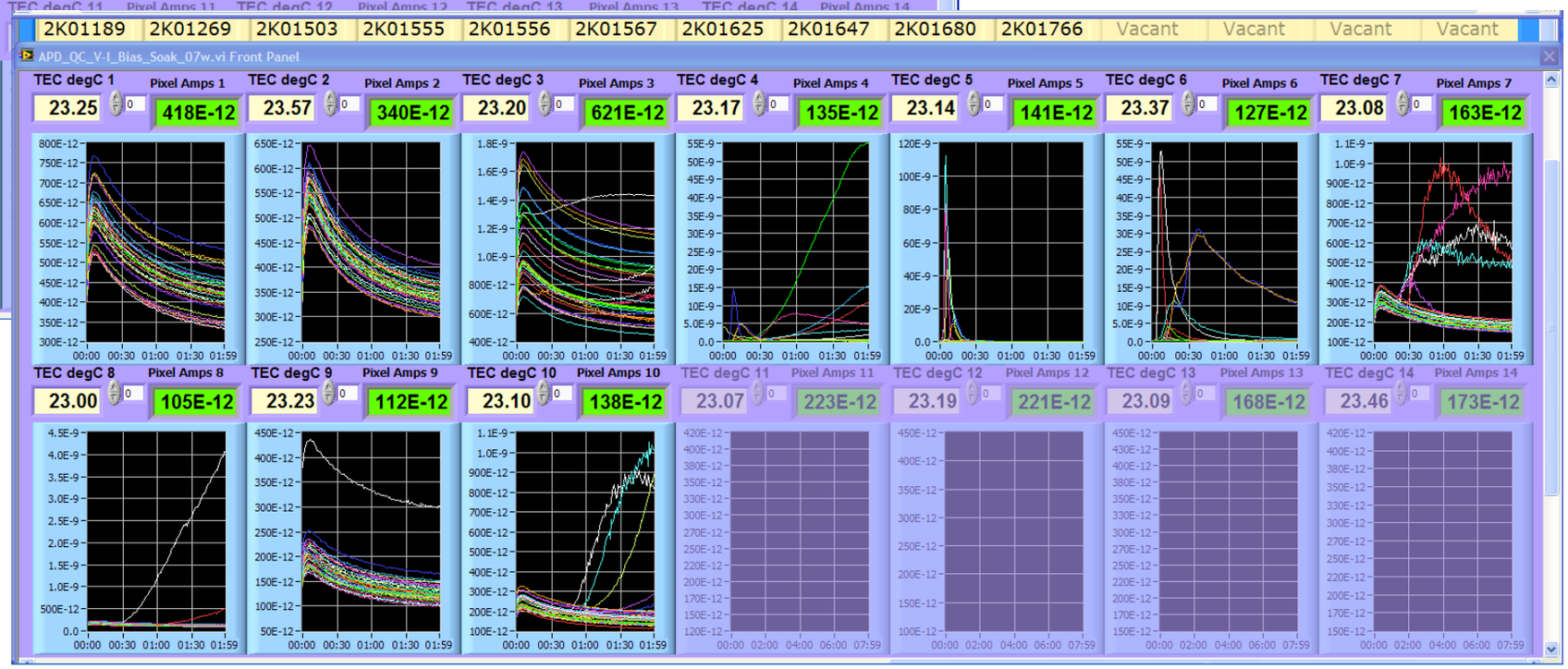
Power Cycle Tests

Test parts over 8 hrs.

Power down for several hours

Re-test for 2 hrs





Lower amplitude transient in 2nd test